Practical Approaches to Green Growth and Sustainable Development with Advanced Computing Technologies

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***Abstract*—**The continuous advancement in technology has lead to exploitation of the environment resulting in increased carbon emission and degraded environment conditions (increased global temperature, melting glaciers, uneven distribution of rainfall, etc).The new era of research and development calls for a sustainable green energy and a two way controlled flow of power for environmental benefits. Smart grid technologies have emerged with a hope for green growth. The use of controllers and feedback systems throughout the network has increased the system resilience lowering the chances of blackouts and minimizing the outages by isolating the disturbances before they can lead to any big damage. A smart grid not only allows a controlled power flow to the utility and the transmission but it also allows the consumer to monitor and control the energy usage by optimizing the 'smart meters'. The smart grid technologies for green energy can further be steadfast by incorporating machine learning for end to end power flow. This paper suggests green growth for economic growth without environmental damage.

Keywords*—Sustainable Development, Smart Grid, Machine Learning, IoT*

I. INTRODUCTION

The potential extension of the renewable energy resources in the smart grid technologies can effectively level up the generation, distribution, transmission and the utilization of the energy. Since the renewable energy resources (hydro, wind, solar, geothermal, etc) are everlasting and cause no threat to the environment hence their incorporation with the traditional generation will aid system reliability. For example, the Sweden government has effectively achieved a renewable energy generation of 40% by solar and wind power generation of their total energy production and they plan to achieve a 100% green energy generation by the year 2040. Similarly other countries can also determine to achieve so by using whatever renewable energy resources they have the best. A smart grid control system has 3 major components:

- Smart meter (record and track the energy consumption & transfer it to AMI)
- AMI center (server that acts as data management system)

II. BACKGROUND

Technological advancements (measured by Information and Communication Technologies or ICT) and green finance are seen as promising solutions. In [1],study uses a statistical model (STIRPAT) and time series data (1995-2020) to analyze the impact of ICT strategies and other factors on Indonesia's ecological footprint (a measure of environmental impact). It finds that:

ICT and green finance have a positive impact on environmental sustainability in both the short and long term. Overall, the study suggests that while economic growth and urbanization create environmental challenges, investing in green technologies and finance can help Indonesia achieve its environmental goals.

The research in [3] highlights the importance of environmental innovation, renewable energy, and green growth for reducing ecological impact. It emphasizes the need for policies that encourage these practices and discourage reliance on traditional financial expansion and non-renewable energy sources. The research offers policy recommendations to address environmental issues, likely focusing on promoting green technologies, renewable energy, and sustainable economic practices, especially for countries with high ecological footprints.

In [4], the researchers dove into the exciting intersection of technology and construction, specifically focusing on how

Artificial Intelligence (AI), Internet of Things (IoT), and big data are transforming the industry. AI, IoT, and big data are merging to create intelligent and sustainable construction practices, embodied by concepts like Construction 4.0 and 5.0. This research explores the challenges and future directions of integrating these technologies in Architecture, Engineering, and Construction (AEC). IoT plays a vital role in collecting real-time data from sensors and devices on construction sites. Advanced Computing Models are used to analyze vast amounts of data to optimize processes and decision-making. Big Data provides the raw data for AI and advanced computing models to function. With Blockchain integration, by combining AI, IoT, and Blockchain can further improve transparency and security in financial transactions, efficiency and sustainability of construction projects.

Big data and V2G technology in creating a stable and efficient smart city [6]. This paper proposes a distributed framework to balance supply and demand within a smart city. The vast amount of data generated in a smart city is crucial for managing the power grid. By analyzing this data, authorities can make informed decisions to prevent outages and instabilities. Vehicle-to-Grid technology, once seen as futuristic, is now being implemented. This allows electric vehicles (EVs) to not only be charged by the grid but also feed excess power back into it, contributing to a more balanced system. The study introduces a novel system to handle the uncertainties associated with vehicle performance and energy resources.

In the research [7], the authors explore deeper into the technical aspects of smart grids and their relationship with renewable energy. They studied that a smart grid isn't a single system, but rather a collection of various renewable energy sources and enabling technologies. Intelligent control plays a central role in optimizing how these resources are used. Smart grids can handle the fluctuating nature of renewable energy sources (like solar and wind) by using advanced control strategies. This ensures a steady flow of power despite the intermittent nature of these resources.

Communication networks and control systems are crucial for monitoring, protecting, and operating the smart grid. These systems can be centralized or decentralized depending on the specific needs. This paper doesn't just discuss these technologies in theory, but offers real-world examples of how they're being used in renewable energy projects within smart cities. Smart Cities are a Meeting Point of Technology and Urban Planning. Technological advancements are driving people to cities, creating a demand for smart cities. Rapid urbanization brings economic benefits but also challenges like pollution and waste management [8].

Smart cities aim to use technology (like the Internet of Things) and infrastructure (sensors, green buildings) to improve citizen well-being and reduce environmental impact. This convergence creates a network of interconnected actors (citizens, businesses, governments) working together for a better urban environment. The technology and infrastructure used in smart cities form a new industry. This industry provides products and services for various sectors, like smart sensors for construction or waste management systems.

It's difficult to assess the economic and environmental impact of smart cities due to their complexity. The authors focuses on the techno-economic perspective by using an economic modeling framework (input-output) to create a composite sector. The study expands the economic model to include data on greenhouse gas emissions from different sectors.

In [9] Internet of Things (IoT) is the demand for real-time data processing and the rapid enhancement of Artificial Intelligence (AI), advanced computing emerges as a crucial pillar part that offering technical support and assurance. This paper provides an overview of advanced computing by introducing the background, basic concepts, development history, and classification. Subsequently, it basically focuses into the concepts, characteristics, and key technologies of edge computing & fog computing, quantum computing, cognitive computing, and ubiquitous computing. Furthermore, it highlights the industrial applications of advanced computing, showcasing its significance in various sectors. Lastly, the paper offers recommendations for the utilization and further advancement of advanced computing technologies.

The researchers [10] studied 5G telecommunication networks adapting to dynamic network conditions becomes imperative, especially with the additional requirements of low latency models and ultra-reliability aspects. This paper presents a novel resource allocation scheme measures basically for 5G networks by leveraging the characteristics of first packet transmission and subsequent retransmissions. The proposed model accurately predicts both system-level and user-level throughput for mobile users, while optimizing network resource utilization. The results demonstrate an 85% accuracy in user-level throughput prediction, validating the effectiveness of the scheme for dynamic resource planning in future networks.

The paper [11] introduced the growing trend and timeliness of big data, along with principles with its management. Various big data processing technologies are introduced, with in-depth analysis provided. The application of the MapReduce paradigm, detailing the process of uploading large volumes of data, processing and analyzing unstructured information, and distributing it into clustered databases. Through practical implementation examples and beautiful insights, the paper

offers valuable perspectives on big data for diverse applications.

In [12] The integration of Information and Communication Technology (ICT) into urban systems has given rise to the concept of smart cities, offering solutions to prevalent urban challenges and fostering economic and social development. This paper explores the evolution, architecture, and sustainability of smart cities, emphasizing their role in enhancing quality of life across domains such as healthcare, education, transportation, and security. It highlights the pivotal role of advanced computational and communication technologies, including IoT, Artificial Intelligence, Blockchain, Big Data, and Cloud Computing, in realizing sustainable smart city development. Operational domains within smart city ecosystems are elucidated, while cyber-physical aspects are briefly discussed. The paper also addresses challenges in deploying advanced technologies and outlines security considerations and solutions for sustainable smart city services. Finally, it suggests future research directions to further enhance smart city innovation and sustainability.

Blockchain technology is increasingly recognized as a fundamental solution for securing real-time applications and their data [13]. In the automotive industry, manufacturers are eager to leverage distributed ledger technology to enhance autonomous vehicles and systems, thereby improving product quality, customer satisfaction, and overall experiences. This paper investigates the significance of blockchain in various autonomous vehicle domains, including Autonomous Electric Vehicles (AEV), Autonomous Underwater Vehicles (AUV), Autonomous Guided Vehicles (AGV), Autonomous Aerial Vehicles (AAeV), and traditional Autonomous Driving. Through a comparative analysis of blockchain-integrated autonomous vehicle systems, the present state and future challenges are identified. Additionally, the study explores sensor utilization, infrastructure requirements, vehicle architectures, driving modes, tracking approaches, intelligent contracts, data handling, and industry-specific use cases. Drawing on recent technologies and practices, this research surveys advancements in autonomous vehicle systems and demonstrates how blockchain can enhance user experiences and industry practices. Finally, the paper outlines limitations, proposes future research directions, and addresses challenges associated with various autonomous vehicle systems, paving the way for further innovation in intelligent transportation.

III. FUTURE WORK

Integrating blockchain technology with artificial intelligence (AI) has significant potential for future research in managing renewable energy within smart grids. This paper emphasizes the complex but crucial role of smart grids in enabling a future powered by renewable energy sources. It highlights the importance of intelligent control, communication systems, and emerging technologies like blockchain and AI in achieving this goal. The emergence of the Smart City Industry as a key economic driver, with both positive and negative environmental impacts. This paper can further be aimed to quantify these impacts to inform future smart city development strategies.

IV. FUTURE WORK

Big data, smart grid and AI integration describes a novel approach to managing a smart city's energy needs by leveraging big data, V2G technology, and a robust framework that considers both energy sources and network design. It suggests using predictive analysis to assess the strength of different network configurations for optimal performance. Smart grids are evolving to handle increasing levels of renewable energy integration. It provides an in-depth analysis of cutting-edge technologies like cloud computing, the Internet of Things (IoT), and blockchain technology.

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